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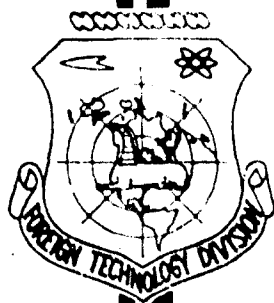# TRANSLATION

ON THE QUALITY OF FILLING FLOATING GYROSCOPIC
INSTRUMENTS WITH A SPECIAL LIQUID

By

Z. F. Vrazayev and V. Yu. Shishmarev

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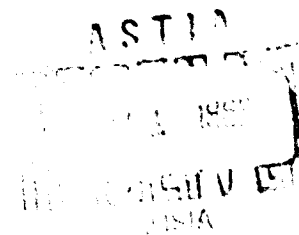
# UNEDITED ROUGH DRAFT TRANSLATION

ON THE QUALITY OF FILLING FLOATING GYROSCOPIC
INSTRUMENTS WITH A SPECIAL LIQUID

BY: Z. F. Urazayev and V. Yu. Shishmarev

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On the Quality of Filling Floating Gyroscopic Instruments
with a Special Liquid.

by

Z. F. Urazayev and V. Yu. Shishmarev

In broad use at present time are integrating and differentiating gyroscopes,
which are used in modern automatic flight control systems, in hydrostabilization sys-
tems for various devices, in autonomous inertia type navigation systems etc.

These instruments should have high accuracy, low sensitivity threshold,greater
er stability of output parameters, vibration resistance, vibration strength, as well
as strength and stability with respect to impacts.

Integrating and differentiating gyroscopes of conventional use in a majority
of cases do not satisfy to a sufficient degree the enumerated requirements. This is
explained by a whole series of causes, the main ones of which are: too great and
inconstant in value friction moment in the bearings of gyroscope frame and in the
mutually moving elements of damper construction, insufficient vibrational and impact
strength and stability, as well as the difficulty of realizing required damping.

Consequently the employment of integrating and differentiating gyroscopes in
modern accurate control systems and measuring was found to be possible only after
solving the problem of reducing the friction moment to a minimum in the frame sup-
ports, creation of a damper, free of dry friction, and increasing the vibrational
strength and stability of the instruments.

This problem was best solved in floating gyroscopes, which are a newer and more
perspective variant of integrating and differentiating gyroscopes. A reduction in
friction moment in these instruments is attained by relieving the bearings on account

of employing the lifting forces of a liquid.

The arrangement of a two-sided floating gyroscope is shown in fig.1. The gyromotor 4 together with the frame is placed in an airtight float 9. On the axis of the float is mounted rotor 6 of the angle indicator and rotor 2 of moments indicator, the stators of which are attached to the common body 10 of the instrument. Between float 9 and body 10 of the instrument is situated the liquid. Since the volume and specific weight of the liquid change substantially with the change in temperature, provisions were made to maintain constant temperature - in the body of the instrument is installed a heating coil 7 and thermo-resistor 8, serving as sensitive element of the thermo-regulator. To compensate the possible changes in the volume of the liquid one face of the body is covered with sylphon 1.
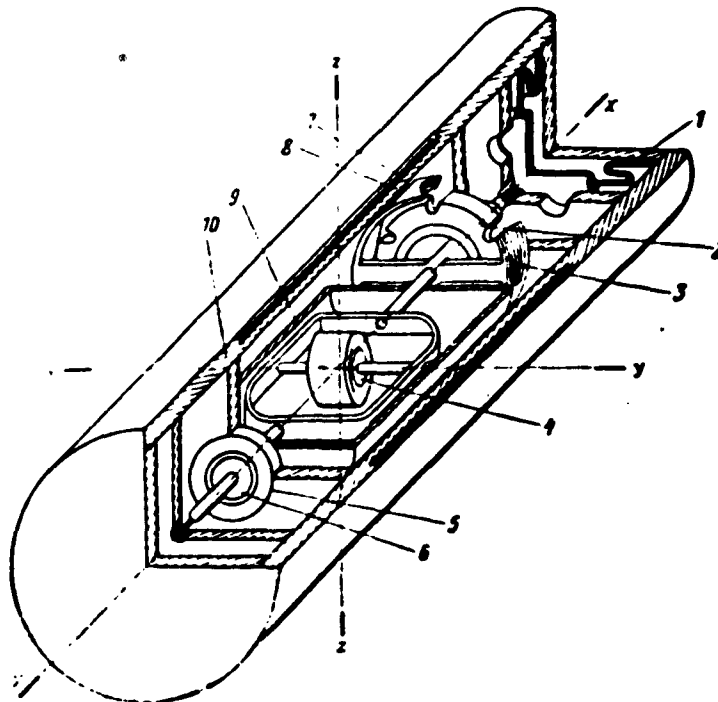


Fig.1.Schematic of two stage floating gyroscope.
1-sylphon; 2-rotor of moments indicator; 3-stator of moment indicator; 4-gyromotor 5-stator of angle indicator; 6-rotor of angle indicator; 7-heating winding; 8-thermo resistance; 9-airtight float; 10-body of instrument.

Volume of the float and specific weight of liquid are selected so that the weight

of the expelled liquid should equal the weight of the floating gyro unit. The gyro unit is thoroughly statically balanced so that its CG coincides practically with the center of pressure, i.e. with the center of gravity of the expelled liquid.

After these conditions are fulfilled the load on the bearings , and consequently also the friction moment in the frame supports become practically equal to zero.

The liquid is used simultaneously for the obtainment of required damping and obtainment of high vibrational and impact strength and stability of these instruments.

One of the important technological problems in the manufacture of floating gyroscopes is the operation of filling the instruments with a special liquid and control of filling quality.

Under the term "filling quality" is understood the absence in the body of the instrument of air bubbles after filling same with liquid. Air bubbles in the body of the instrument have a negative effect on it performance , because the air bubble adhering to the floating gyro unit may move over the surface of the gyro unit and, producing harmful moments, will bring about the appearance of false output signals of the gyroscope and their instability.

Furthermore, when an air bubble is present in the liquid it may distort the magnitude of the damping moment, which is absolutely prohibitted in integrating gyroscopes, where the moment, produced by the damper, appears to be                the measuring one.

Hence it follows, that the operation of filling should be carried out with greater thoroughness, and the method of controlling the quality of filling should assure reliable measurement of the air bubble volume, remaining in the instrument after filling same with special liquid.

Filling of instruments is done on a special installation (fig.2). Instrument 1 is placed in a contrivance 2 for mechanical pumping, and tubes 6 and 7 are connected to nipples of the instrument. After this with the aid of mechanism 14 is lowered

bell 10., the vacuum pump is connected and valve 8 is opened. The magnitude of the remanent pressure, controllen by vacuummeter 12, should be not more than 5 mm Hg. After the air bubbles have been separated from the liquid into flask 4, but not earlier than 3 hours from the beginning of vacuuming, should the filling begin. To do this tumbler $T_1$ connects the attachments for mechanical pumping, and with the aid of tumbler 2,motor and reductor valve 5 is shifted into "open " position.

After the appearance of liquid, which passed through the instrument, in flask 3 above the level of marker $M$, but not sooner than within 3 hours from the beginning of filling, valve 8 is closed and the vacuuming is discontinued.

Then is disconnected the contrivance for mechanical pumping, valve 5 is shut and with the aid of valve 9 the pressure under the bell rises to atmospheric. A reduction in the level of liquid in flask 3 should not be greater than the given allowance $\triangle H$, the magnitude of which is ordinarily set up experimentally.

After this the bell is lifted, the instrument is disconnected from the installa tion and the openings in the connecting pieces of the instrument are choked off.

The filled instrument is then held for two hours in a thermostat at a temperature of + 50°C and is cooled in the air to normal temperature of $20 \pm 5°$ C for no less than two hours, after which the presence of an air bubble in the instrument is checked.

The evaluate the filling quality of practical interest is the evaluation of the relationship between residual summary volume of air bubble in the filled instru- ment and the magnitude of drop in liquid level $\triangle H$ in flask 3.

We will determine the ratio between volume of air bubble in the instrument and the liquid level drop in flask 3 by the value $\triangle H$.

We will assume that in the instrument after filling the liquid remained a certain volume of air $v_B$ at a remanent pressure under the bell $p_B$.When the pressure under the bell is raised to atmospheric $p_a$, the volume of the air bubble in the instrument will decrease to a value $v_a$.

Fig.2.Installation for filling instrument with special liquid.
1-instrument being filled; 2-contrivance for mechanical pumping; 3-metering flask;
4-flask for special liquid; 5-valve,connected through reductor with electromotor 6;
7-rubber vacuum tubes; 8-valve with valve 9; 10-glass bell; 11- table; 12-vacuum-
meter; 13- technological connecting piece; 14-bell raising mechanism; 15-protective
cylinder for transparent Flexiglass; 16-reductor; 17-electric motor,$T_1$ and $T_2$- tumblers,
14-graduation on metering flask.

It is apparent that $v_B \cdot p_B = v_a p_a$. (1)

The magnitude of the volume $v_a$ can be indirectly determined by the magnitude of

liquid level drop in flask 3 from equation:

$$v - v_a = \frac{\pi d^2}{4} \cdot \Delta H,$$  (2)

where d - internal diameter of flask in mm; $\Delta H$ - magnitude of liquid level drop in

flask in mm.

Expression (1) can be written in form of

$$v_b = \frac{v_a \cdot p_a}{p_b}.$$  2a

then instead of equation (2) we will have:

$$\frac{p_b}{p_a} - v_a = \frac{\pi d^2}{4} \cdot \Delta H$$  2b

or

$$v_a \left( \frac{p_a}{p_b} - 1 \right) = \frac{\pi d^2}{4} \cdot \Delta H.$$  (3)

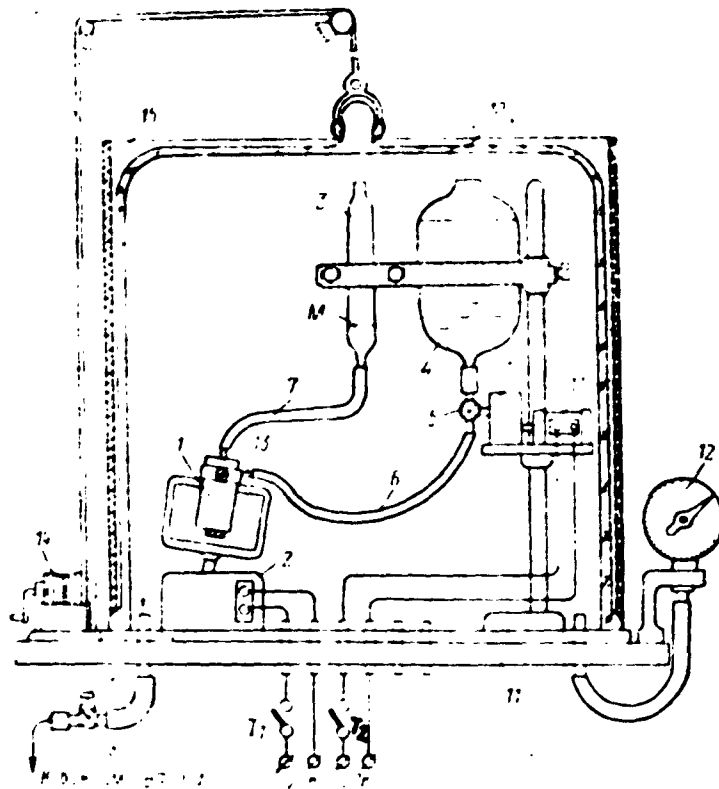But since $p_a/p_B$ is much greater than 1, then with practically sufficient accuracy it

Figure 2

can be written

$$\frac{r_a}{r_1} = \frac{r_d}{r_1} \Delta H \qquad 3a$$

or

$$v_s = \frac{\pi d^2}{4} \cdot \frac{p_0}{p_a} \cdot \Delta H. \qquad (4)$$

Example. Assuming at d = 15 mm and at a rise in pressure from $p_B$=3 mm Hg to $p_a$ = 760 mm Hg the drop in liquid level in flask $\triangle$H = 2 mm.

The summary value of the air bubble volume in the instrument at atmospheric pres sure $p_a$ is determined from expression (4):

$$v_s = \frac{\pi d^2 \cdot r_0}{4} \cdot \Delta H = \qquad 4a$$

If the permissible value of the air bubble volume $v_{a\ perm}$ is known, it is then possib le to determine the permissible value of liquid level reduction in flask 3, at a change in pressure und r the bell from $p_B$ to $p_a$ from the following expression:

$$\Delta H_{aom} \leqslant \frac{4 v_{a\ perm} \cdot p_a}{\pi d^2 \cdot p_n}. \qquad 5$$

But reliable filling quality control by the above described method is difficult, because in terms (4) and (5) figures a liquid level drop value $\triangle$H in flask 3,the measu rement of which with a sufficient degree of accuracy appears to be impossible. There fore the presence of an air bubble in instruments filled with liquid is checked on a special installation (fig.3)by an indirect method by the "movement" of the sylphon.

To the body of instrument 1 is fastened with bolt 5 bushing 4 with indicator 6. The shank of the indicator is brought down to the bottom of the sylphon and a 1 mm tension is made along the indicator scale. The instrument is placed on pedestal 2 under cover 10, the vacuum pump is connected and valve 7 is opened. After a given rare faction is created under the cover (usually 3-5 mm $H_g$) it is kept there for 5 minutes and the first instrument indication is determined. Then with the aid of valve 8 the air pressure under the cover is raised to atmospheric and the second indicator reading is determined.

The difference between second and first indicator readings represents the "movement" of the sylphon.

The movement of the sylphon should not exceed the value,indicated in the drawing for given instrument.
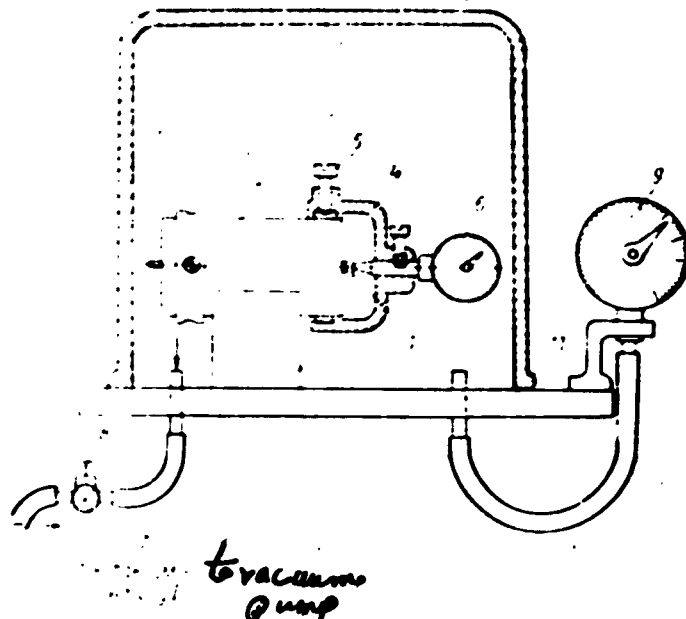


Fig.3.Schematic of the installation for measuring sylphon movement.
1-instrument; 2-pedestal; 3-technological screw; 4- bracket; 5-screw for attaching bracket to instrument. 6-indicator with 0.01 mm graduation. 7-spigot with valve 8, 9- vacuummeter; 10-airtight cover with peeping window or glass bell; 11-table.

We shall determine the ratio between the volume of the air bubble in the instrument and the movement of the sylphon. If under the cover was an atmospheric pressure $p_a$ and in the instrument was an air bubble with a volume $v_a$,then when reducing the pressure under the cover to a value $p_B$ the volume of the air bubble will rise to a certain value $v_B$. This increase in volume of air bubble will take place on account of sylphon movement by a certain value S. The relationship between the values S and $v_a$ can be established from the following considerations.

After setting the indicator shank with a 1 mm tension to the bottom of the sylphon and at a pressure under the cover $p_a$, the air bubble with a volume $v_a$ is under a pressure:

$$p_a + \frac{P_{meas}}{F_{eff}} \cdot \qquad 5a$$

where

$P_{meas}$= 0.2 kg - measured force of indicator;

$F_{eff}$ - effective area of sylphon in $cm^2$.

After under the bell has been created a          vacuum with remnant pressure $p_B$

and the bottom of the sylphon has shifted by a value S, the air bubble will be under

pressure

$$p_a T \frac{\cdots}{\cdots} + \frac{\cdots}{\cdots} \cdot S \quad 5 \ell$$

where j- rigidity of sylphon, i.e. the force, under the effect of which the sylphon stretches by 1 mm (in kg/mm).

It can be written:

$$v_a \left( p_a + \frac{\cdots}{\cdots} \right) = \cdots \left( p_a \quad \frac{\cdots}{\cdots} \quad \cdots \quad S \right). \tag{6}$$

$$\cdots \cdots = F_{\cdots} \cdot S \tag{7}$$

Expression (6) can be written in form of:

$$v_a \quad v \quad \begin{array}{c} \cdots + \cdots \cdot \text{Charge} \cdot \text{eff} \\ \cdots \text{charge} \cdot S \\ \cdots + \cdots \cdot \text{eff} \cdot \cdots \cdot \text{eff} \end{array} \tag{8}$$

Substituting expression (8) in (7); we will obtain

$$v_a \cdots \quad \frac{\cdots + \frac{p_{\cdots}}{\cdots} \cdot \text{eff} - 1}{p_a + \cdots \cdot \text{eff} \cdots \text{eff}} = F_{\cdots} \cdot S \tag{8a}$$

Transforming the obtained expression, we will obtain

$$v_a \cdots \quad \frac{\cdots \text{eff} \quad \text{change} + (JS)}{\cdots - \cdots - \left( \frac{JS}{\cdots} \right) \text{eff}} S. \tag{9}$$

In this equation the members $p_B$; $jS$; $jS/F_{eff}$ marked by the sign * can be disregarded in view of their smallness. In addition, it can be assumed, that $p_a = 760$ mm Hg = 1 kg/ cm$^2$ = const, then equation 9 will acquire the following form:

$$\cdots = (p_{\cdots} F_{eff} + p_{\cdots})S \tag{10}$$

Example. The instrument has a sylphon with effective area $F_{eff}$ = 12.56 cm$^2$ and a rigidity j = 0.8 kg/cm. During rarefaction from atmospheric pressure $p_a$ = 760 mm Hg = 1 kg/cm$^2$ to a pressure $p_B$ = 5 mm Hg = 0.0066 kg/cm$^2$ the movement of the sylphon meas ured by the indicator S = 0.05 mm; the measuring force of the indicator $P_{meas}$ = 0.2 kg.

We will determine the volume of the air bubble in the instrument by formulas (9) and (10).

a) By formula (9);

$$\mathbf{v} = \text{(illegible)} \qquad 10a$$

b) by formula (10):

$$v_a = \text{(illegible)} \qquad 10b$$

The magnitude of the error when calculating the volume of the bubble by formula (10) equals

$$\Delta v_a = \frac{v_{a(10)} - v_{a(9)}}{v_{a(9)}} \cdot 100\% , \qquad 10c$$

where $\Delta v_a$ - error in calculating by simplified formula (10) in %;

$v_a(10)$- volume of air bubble, calculated by formula (10);

$v_a(9)$ - volume of air bubble, calculated by formula (9).

in our example $\qquad \Delta v_a = \frac{1.11 - 1.11}{1.11} \cdot 100 = . \qquad 10d$

Consequently, the volume of the air bubble in the instrument can be determined with practically sufficient accuracy by the simplified formula (10).

For concrete construction of the instrument the effective area of the sylphon and its rigidity appear to be constant values. In addition, for concrete setting to control the volume of the air bubble the magnitude of remanent pressure $p_B$ and the measuring force of the indicator $P_{meas}$ also appear to be constant. Consequently formula (10) can be written in form of

$$v_a = c \cdot S, \qquad (11)$$

where $c = p_B \cdot F_{eff} + P_{meas}$.

In this way, the magnitude of sylphon movement S characterizes absolutely the volume of the air bubble, remaining in the instrument after filling same with liquid.

To assure accuracy and reliability in measuring the volume of the air bubble it is necessary, that the magnitude of the measuring force of the indicator $P_{meas}$ should be by an order lower than the product $p_B \cdot F_{eff}$. In our example this product has the value

$$p_B \cdot F_{eff} = 0.0066 \cdot 12.56 = 0.0827 \ kg = 83 \ g. \qquad 11a$$

Consequently, the measuring force $P_{meas}$ should be not more than $10 \div 20$ g.

Furthermore, it is necessary, that its force should be constant, because fluctuations in the value $P_{meas}$ will directly affect the accuracy of measuring the volume of the air bubble.

In connection with all that has been said, the obtained application of indicators with measuring force $P_{meas} = 200-300$ g to evaluate the filling quality of instrument should be considered as a failure. For these control systems should be recommended instruments with low metering force, e.g. micro cators. The existing method and means of filling instruments with special liquid allow to attain only such filling quality, at which in the body of the instrument remains a summary air bubble of the magnitude of $1-2$ mm$^3$. For many modern instruments this filling quality cannot be considered as sufficient. Therefore, the methods and means of filling require improcement.

### Literature

Slavyanskiy G.A; Pryadilov,Yu.N.Floating Gyroscopes and their Application,Oborongiz 1958.

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